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PULSED FIELD USER PROGRAM

ATTENTION USERS: Alex H. Lacerda

The Pulsed Field Facility of the NHMFL continues to maintain its role as a world leader in the field of strong correlated electron systems at extreme conditions of high magnetic field, low temperature, and high pressure. The following research by Marcelo Jaime, Kee-Hoon Kim, and Neil Harrison of the NHMFL Pulsed Field Facility and John Mydosh of Leiden University represents significant results in this field. The resulting phase diagram of URu_2Si_2 was recently featured on the cover of *Physical Review Letters*, **90**, 096402 (2003). This is an excellent example of the valuable scientific collaborations constantly being made between the NHMFL users program and the outside scientific community. Furthermore, this experiment was also a joint project among facilities as research was conducted at both the Los Alamos andTallahassee campuses of the NHMFL.

Magnetic-Field-Induced Critical Behavior in the Hidden-Order Compound URu_2Si_2

M. Jaime *et al. Physical Review Letters*, ***89***, *287201 (2002)*
N. Harrison *et al., Physical Review Letters*, ***90***, *096402 (2003)*

Almost two decades have been passed and a clear understanding of the intriguing second order phase transition ($T_0 \sim 17$ K) of URu_2Si_2 is still missing. Recently, a great amount of experimental and theoretical work utilizing high magnetic field as an external parameter initiated a real renaissance of heavy fermion physics and particularly the physics related to URu_2Si_2.

To that end, NHMFL – Pulsed Field Facility scientists, in collaboration with J. Mydosh (Leiden University), investigate the temperature and magnetic field dependences of the specific heat, magnetization and resistivity of URu_2Si_2 from $T \approx 0.5$ K to 20 K in continuous and pulsed magnetic fields up to 50 T. The specific heat vs. temperature at constant magnetic field shows that the transition at $T_0 = 17$ K is shifted to lower temperatures and sharpened when the magnetic field increases, and is completely suppressed at H ≈ 35.5 T. Between ~36 T and ~39 T we observe a new first-order anomaly in the specific heat vs. temperature. Above 40 T a Schottky-like contribution develops. Evidence is found of metamagnetism at $H \approx 38$ T. In the close proximity of the metamagnetic transition, *quantum critical* behavior is observed in the temperature dependence of the resistivity.

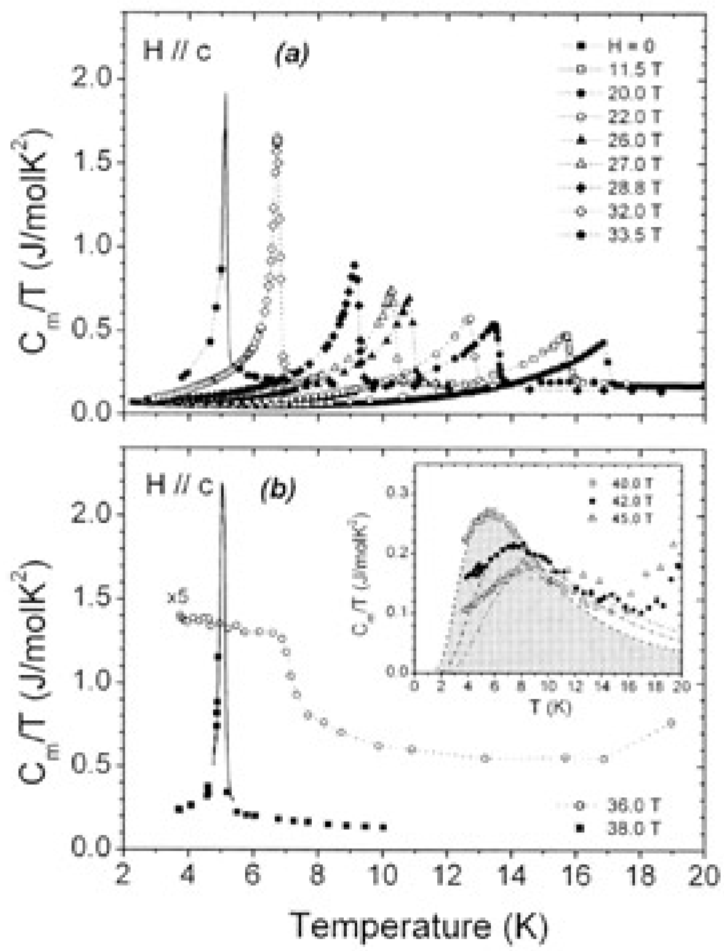

Figure 1. (a) C_m/T vs. T measured at constant magnetic fields up to 33.5 T. Symbols correspond to thermal relaxation method, solid lines to large delta T method [12], and dotted lines are guides to the eye. (b) C_m/T vs. T for H = 36 and 38 T. Inset: C_m/T vs. T for H = 40, 42, and 45 T. Dashed lines are fits with a Schottky expression.

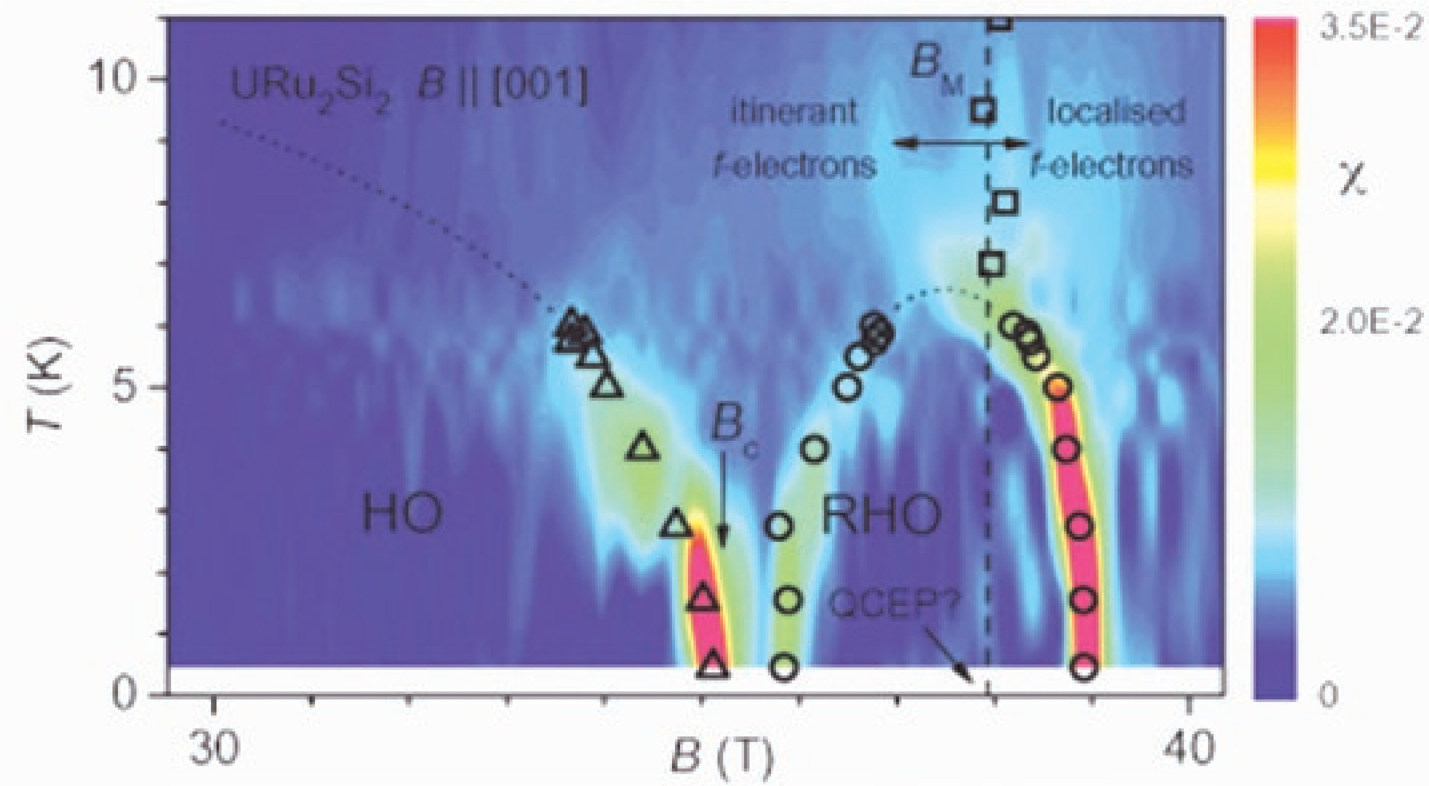

Figure 2. Color intensity plot of the magnetic susceptibility of URu_2Si_2 on traversing the hidden order (HO) and reentrant (RHO) phases measured in pulsed magnetic fields. The term “hidden order” refers to the low temperature phase in which the order parameter is yet to be identified. The RHO phase is believed to be created in the vicinity of a metamagnetic quantum critical end point. (Recently featured on front cover of *Physical Review Letters*, **90**, 096402 (2003)).

Figure 1 shows measurements of C/T vs. T in a single crystal oriented with the crystallographic c-axis along the magnetic field. Figure 1(a) displays $C_m/T=(C_{tot}-C_{ph})/T$ vs. temperature for magnetic fields up to 33.5 T. We observe the anomaly at T_0 shifting and becoming sharper and more symmetric with increasing external field. The sharpening of the anomaly indicates a gradual switch from second order to first order in temperature. Figure 1(b) displays C_m/T measured at 36 T and 38 T. At slightly higher field, $H = 38$ T yet another large anomaly develops in C_m/T, which in turn is suppressed with a magnetic field of 40 T. Figure 1 (b) inset shows C_m/T measured at $H = 40$, 42, and 45 T. For this extreme field regime all that is left in C_m is a Schottky-like anomaly.

Figure 2 shows a phase diagram of compiled of pulsed field isothermal magnetization (for H // c-axis) *M(H)*. $M(H)$ at 7 K and 8 K show an inflection point (H_M), which we attribute to a metamagnetic transition indicating a crossover from itinerant f-electron behavior (low H) to localized f-electron physics (high H). When the temperature is reduced below 6 K the inflection point is replaced by a cascade of sharp transitions, one at each of several new phase boundaries. Combining the information obtained from *M(H), C(H),* and $\rho(T, H)$, a revised phase diagram for URu_2Si_2 displayed in Figure 2 in which the new phases are evident. It is interesting to notice that all these three lines seem to converge at a hypothetical quantum critical point at $H \approx 38$ T at $T = 0$.

The magnetic field induced quantum criticality in this material is an excellent example of where the right combination of low temperature and high magnetic field allows the authors to reveal new phases not possible to be observed before.